US009351428B2

(12) **United States Patent**
Eckberg et al.

(10) **Patent No.: US 9,351,428 B2**
(45) **Date of Patent: May 24, 2016**

(54) **BLIND DOCKING APPARATUS TO ENABLE LIQUID COOLING IN COMPUTE NODES**

(71) Applicant: **Lenovo Enterprise Solutions (Singapore) Pte. Ltd.**, Singapore (SG)

(72) Inventors: **Eric A. Eckberg**, Rochester, MN (US); **Brian M. Kerrigan**, Cary, NC (US); **Robert M. Lindsay**, Raleigh, NC (US); **Michael S. Miller**, Raleigh, NC (US); **Derek I. Schmidt**, Raleigh, NC (US); **James S. Womble**, Hillsborough, NC (US)

(73) Assignee: **Lenovo Enterprise Solutions (Singapore) Pte. Ltd.**, Singapore (SG)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 125 days.

(21) Appl. No.: **14/472,608**

(22) Filed: **Aug. 29, 2014**

(65) **Prior Publication Data**

US 2016/0066480 A1 Mar. 3, 2016

(51) **Int. Cl.**

F16L 37/26	(2006.01)
F16L 37/30	(2006.01)
H05K 7/20	(2006.01)
F16L 37/34	(2006.01)

(52) **U.S. Cl.**

CPC ***H05K 7/20772*** (2013.01); ***F16L 37/26*** (2013.01); ***F16L 37/30*** (2013.01); ***F16L 37/34*** (2013.01); ***H05K 7/20272*** (2013.01)

(58) **Field of Classification Search**

CPC H05K 7/20772; H05K 7/20272; F16L 37/26; F16L 37/30; F16L 37/34

USPC 137/614, 614.03–614.05

See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

3,774,636	A *	11/1973	Arita	F16L 37/32 137/614.04
5,263,871	A	11/1993	Sano	
6,407,923	B1	6/2002	Gerlock et al.	
6,860,290	B2 *	3/2005	Knuthson	F16L 37/30 137/594

(Continued)

FOREIGN PATENT DOCUMENTS

EP	1448040	A2	8/2004

OTHER PUBLICATIONS

J.C. Parrilla et al., "Packaging the IBM eServer z990 central electronic complex", IBM J. Res. & Dev. vol. 48 No. 3/4 May/Jul. 2004, pp. 395-407.

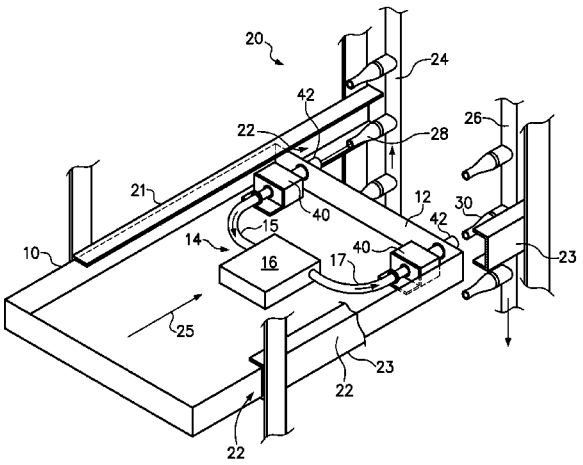
Primary Examiner — Kevin Lee

(74) *Attorney, Agent, or Firm* — Katherine S. Brown; Jeffrey L. Streets

(57) **ABSTRACT**

An apparatus includes a rigid structure having first and second collars, a quick connect connector having first and second shoulders, and a spring biasing the connector toward an extended position with the first shoulder against the first collar and the second shoulder against the second collar. The first collar and the first shoulder form an inwardly and rearwardly angled contact surface there between, and the second collar and the second shoulder form an inwardly and rearwardly angled contact surface there between. The connector is centered in the first and second collars unless acted upon by a force overcoming the spring and pushing the connector to a retracted position with the first and second shoulders out of contact with the first and second collars. When retracted, the connector may adjust its position longitudinally, vertically, laterally or angularly to facilitate coupling with a mating fixed quick connect connector.

20 Claims, 4 Drawing Sheets



(56) **References Cited**

U.S. PATENT DOCUMENTS

7,465,177	B2	12/2008	Wood	
8,336,922	B2 *	12/2012	Tiberghien et al.	F16L 37/56 137/594
9,194,634	B2 *	11/2015	Tiberghien et al.	F28F 27/00
2011/0044010	A1	2/2011	Ledezma et al.	
2012/0327602	A1	12/2012	Kulkarni et al.	
2013/0322016	A1	12/2013	Jones et al.	
2013/0344748	A1	12/2013	Phan	

* cited by examiner

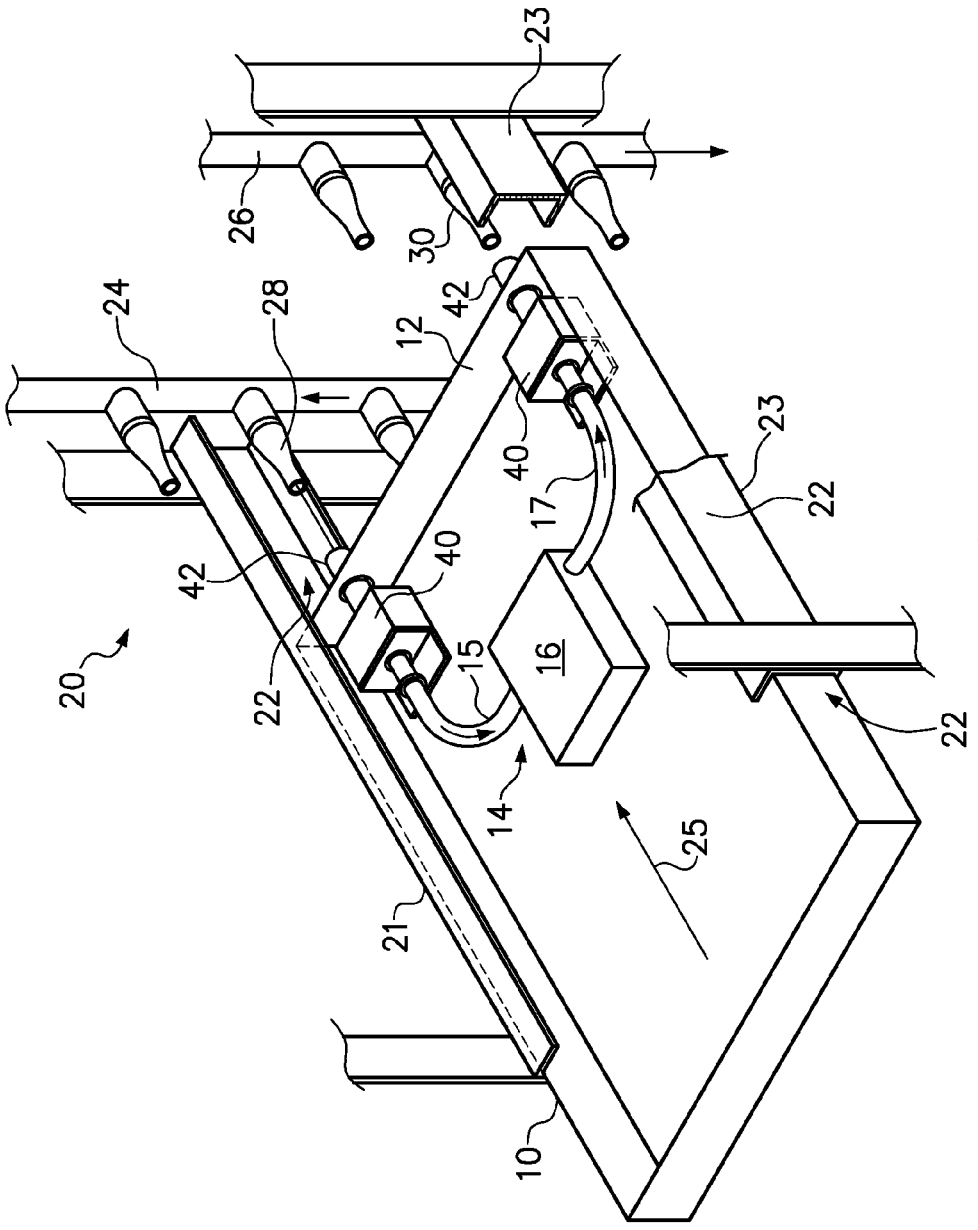


FIG. 1

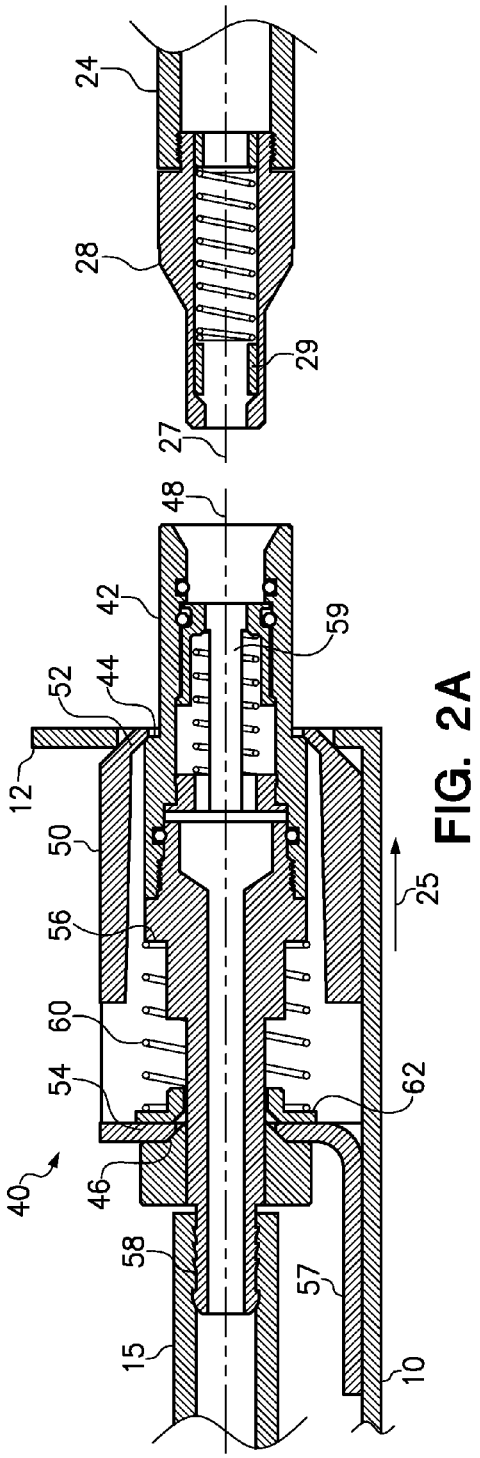

24
28
29
27
48
42
59
52
44
12
50
56
60
54
40
46
58
57
15
10
62
25

FIG. 2A

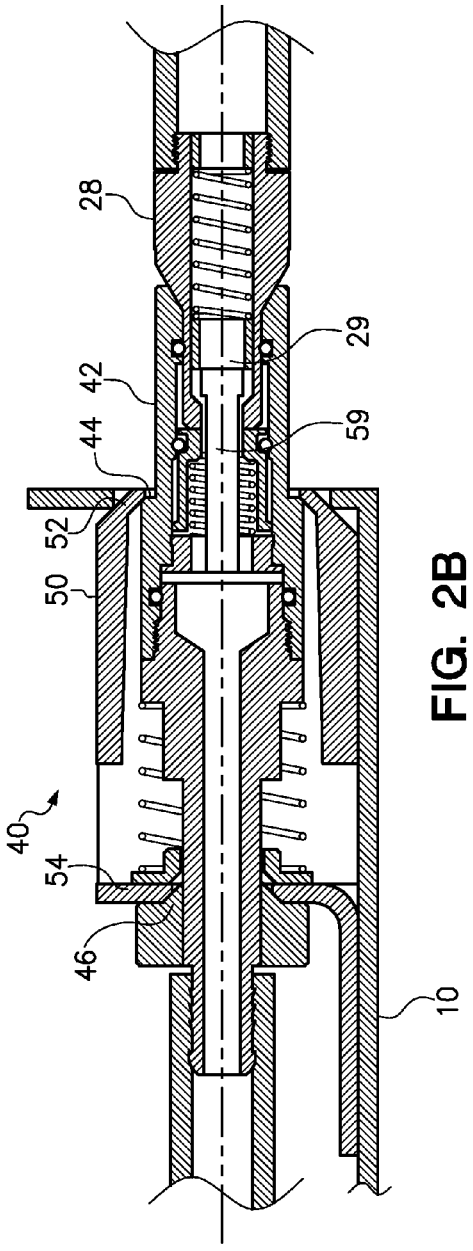

28
29
42
59
44
52
50
40
54
46
10

FIG. 2B

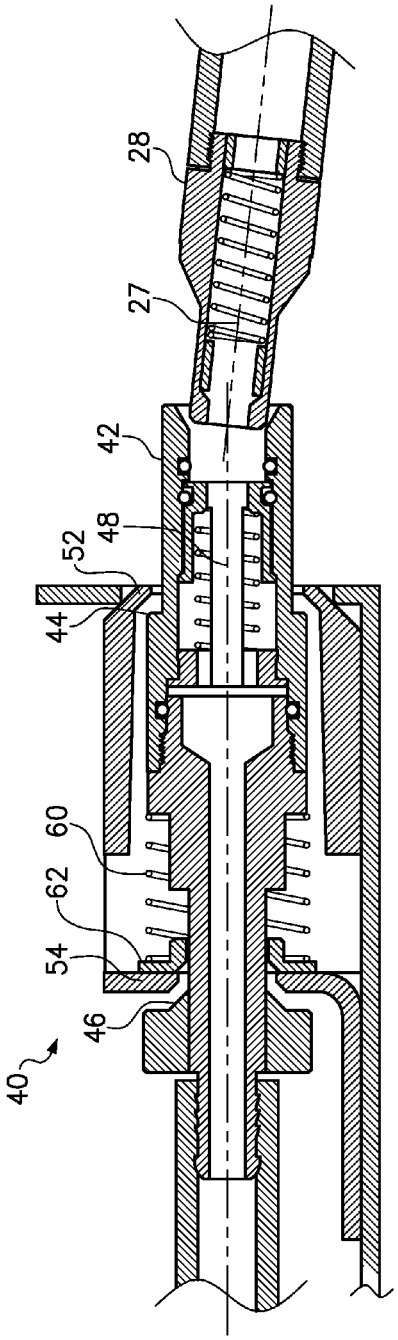


FIG. 3A

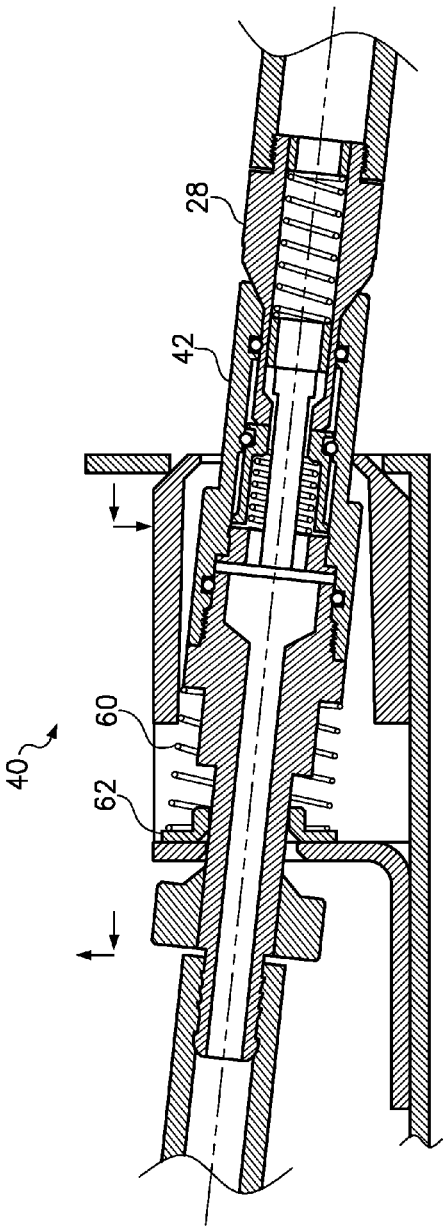


FIG. 3B

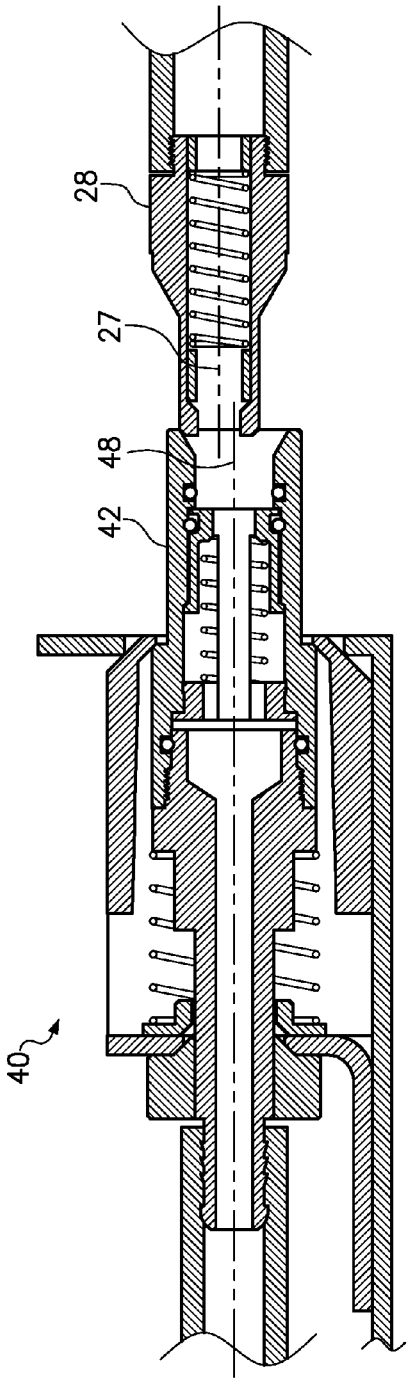


FIG. 4A

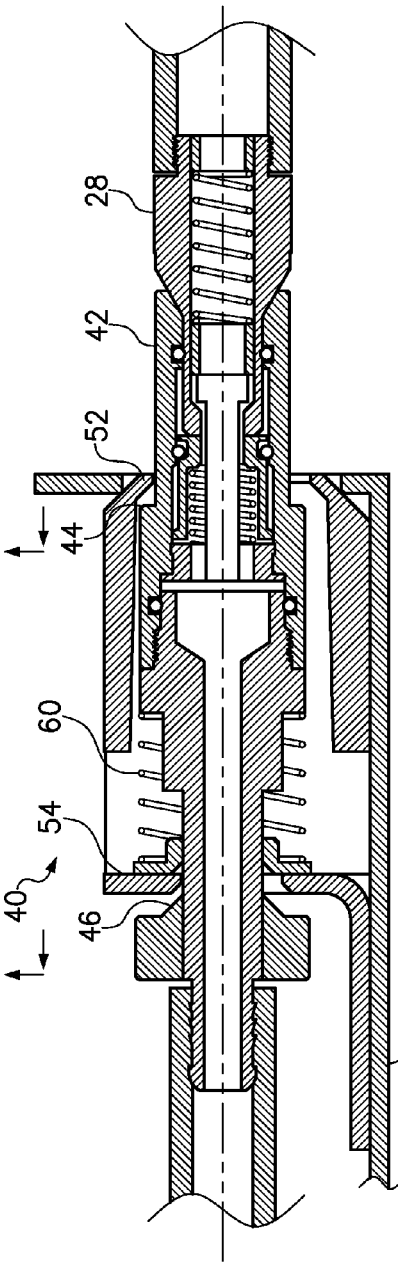


FIG. 4B

BLIND DOCKING APPARATUS TO ENABLE LIQUID COOLING IN COMPUTE NODES

BACKGROUND

1. Field of the Invention

The present invention relates to blind docking of fluidic conduits between a two components.

2. Background of the Related Art

Heat-generating computer system components, such as processors, are generally supported within a chassis, such as a server rack, to provide efficient storage and accessibility for component installation and removal. In high heat-density systems, a coolant such as water may be provided from a coolant source and flow through a supply conduit to one or more heat exchangers disposed within or adjacent to the chassis. The coolant may be continuously warmed at the one or more heat exchangers, and the warmed coolant may be returned to the coolant source through a return conduit or released without recirculation. Where warmed coolant is returned to the coolant source, the returned coolant may be cooled by a regenerator, such as a cooler or refrigeration system, so that the regenerated coolant may be circulated back through the supply conduit. The supply conduit and the release or return conduit are portions of a fluidic circuit.

In conventional fluidic circuits for coolant systems, the supply conduit and the release or return conduit may include fluidic couplings, such as mating threaded fittings or mating flanges, that facilitate the connection of fluid conduits that deliver the fluid to one or more heat exchangers in the chassis. Threaded and flanged fittings generally take a large amount of time and effort to make up (connect) and break out (disconnect). An alternate type of coupling is a quick disconnect coupling comprising a male insert that is releasably receivable in a female socket to sealably and fluidically couple a first portion of a conduit connected to the male insert to a second portion of a conduit connected to the female socket. Used in this manner, a first quick disconnect coupling may be used to connect a fluid coolant supply conduit to an inlet conduit to one or more heat exchangers within a chassis and a second quick disconnect coupling may be used to connect a fluid coolant release/return conduit to an outlet conduit from the one or more heat exchangers. In this manner, first and second quick disconnect couplings may be used to quickly provide a fluidic circuit to remove heat produced by heat-generating electronic components within the chassis.

Although connecting and disconnecting quick disconnect couplings requires less time than conventional fluidic couplings, a substantial amount of effort and time may still be required to make up a pair of quick disconnect couplings to enable the fluidic circuit, especially if the quick disconnect couplings are disposed in a location that is difficult to access such as at the back of a computer chassis. For example, a user may have to align a first male insert with a first female socket, insert the first male insert into the first female socket, secure the quick disconnect coupling by sliding a release collar on the female socket to a docked position, and then repeat the process on a second conduit to complete the fluid circuit.

BRIEF SUMMARY

One embodiment of the present invention provides an apparatus comprising a chassis and a compute node. The chassis includes a fluid supply conduit, a fluid return conduit, a first quick connect connector that is fluidically coupled to the fluid supply conduit, a second quick connect connector that is fluidically coupled to the fluid return conduit, and a bay configured to receive the compute node. The first and second quick connect connectors are secured in a fixed position at the back of the bay and are oriented in a forward direction into the bay. The compute node has a rearward end securing a first compliant connector assembly and a second compliant connector assembly, wherein the first compliant connector assembly includes a third quick connect connector oriented in a rearward direction so that installing the compute node within the bay provides nominal alignment of the third quick connect connector with the first quick connect connector, and wherein the second compliant connector assembly includes a fourth quick connect connector oriented in a rearward direction so that installing the compute node within the bay provides nominal alignment of the fourth quick connect connector with the second quick connect connector. The third quick connect connector has first and second shoulders and the fourth quick connect connector has first and second shoulders. The first compliant connector assembly includes a rigid structure having first and second collars, wherein the first collar and the first shoulder form an inwardly and rearwardly angled contact surface there between, and wherein the second collar and the second shoulder form an inwardly and rearwardly angled contact surface there between. The first compliant connector assembly further includes a first spring biasing the third quick connect connector in the rearward direction. Similarly, the second compliant connector assembly includes a rigid structure having first and second collars, wherein the first collar and the first shoulder form an inwardly and rearwardly angled contact surface there between, and wherein the second collar and the second shoulder form an inwardly and rearwardly angled contact surface there between. The second compliant connector assembly further includes a second spring biasing the fourth quick connect connector in the rearward direction.

Another embodiment of the present invention provides an apparatus comprising a compute node configured to be received within a chassis bay, and a first compliant connector assembly secured to a rearward end of the compute node. The first compliant connector assembly includes a rigid structure having first and second collars, a first quick connect connector having first and second shoulders, and a first spring biasing the first quick connect connector in the rearward direction. The first collar and the first shoulder of the first compliant connector assembly form an inwardly and rearwardly angled contact surface there between, wherein the second collar and the second shoulder of the first compliant connector assembly form an inwardly and rearwardly angled contact surface there between, and wherein the first quick connect connector is oriented in a rearward direction for blind mating with a second quick connect connector within the chassis bay.

Yet another embodiment of the present invention provides an apparatus comprising a rigid structure having first and second collars, a quick connect connector having first and second shoulders, and a spring biasing the quick connect connector toward an extended position with the first shoulder against the first collar and the second shoulder against the second collar. The first collar and the first shoulder form an inwardly and rearwardly angled contact surface there between, and the second collar and the second shoulder form an inwardly and rearwardly angled contact surface there between. The quick connect connector is centered in the first and second collars unless acted upon by a force overcoming the spring and pushing the quick connect connector to a retracted position with the first and second shoulders out of contact with the first and second collars.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

FIG. **1** is a perspective view of a compute node being installed into a bay of a chassis or rack in order to blind mate a pair of fluid couplings.

FIG. **2**A is a cross-sectional diagram of a compliant quick connect connector that is axially aligned for coupling to a mating fixed quick connect connector.

FIG. **2**B is a cross-sectional diagram of the compliant quick connect connector coupled to the fixed quick connect connector of FIG. **2**A to provide fluid communication there between.

FIG. **3**A is a cross-sectional diagram of a compliant quick connect connector that is angularly misaligned with a mating fixed quick connect connector.

FIG. **3**B is a cross-sectional diagram of the compliant quick connect connector coupled to the fixed quick connect connector of FIG. **3**A to provide fluid communication there between.

FIG. **4**A is a cross-sectional diagram of a compliant quick connect connector that is vertically misaligned with a mating fixed quick connect connector.

FIG. **4**B is a cross-sectional diagram of the compliant quick connect connector coupled to the fixed quick connect connector of FIG. **4**A to provide fluid communication there between.

DETAILED DESCRIPTION

One embodiment of the present invention provides an apparatus comprising a chassis and a compute node. The chassis includes a fluid supply conduit, a fluid return conduit, a first quick connect connector that is fluidically coupled to the fluid supply conduit, a second quick connect connector that is fluidically coupled to the fluid return conduit, and a bay configured to receive the compute node. The first and second quick connect connectors are secured in a fixed position at the back of the bay and are oriented in a forward direction into the bay. The compute node has a rearward end securing a first compliant connector assembly and a second compliant connector assembly, wherein the first compliant connector assembly includes a third quick connect connector oriented in a rearward direction so that installing the compute node within the bay provides nominal alignment of the third quick connect connector with the first quick connect connector, and wherein the second compliant connector assembly includes a fourth quick connect connector oriented in a rearward direction so that installing the compute node within the bay provides nominal alignment of the fourth quick connect connector with the second quick connect connector. The third quick connect connector has first and second shoulders and the fourth quick connect connector has first and second shoulders. The first compliant connector assembly includes a rigid structure having first and second collars, wherein the first collar and the first shoulder form an inwardly and rearwardly angled contact surface there between, and wherein the second collar and the second shoulder form an inwardly and rearwardly angled contact surface there between. The first compliant connector assembly further includes a first spring biasing the third quick connect connector in the rearward direction. Similarly, the second compliant connector assembly includes a rigid structure having first and second collars, wherein the first collar and the first shoulder form an inwardly and rearwardly angled contact surface there between, and wherein the second collar and the second shoulder form an inwardly and rearwardly angled contact surface there between. The second compliant connector assembly further includes a second spring biasing the fourth quick connect connector in the rearward direction.

Quick connect couplings are well-known couplings that allow quick and easy connections, such as between two fluid conduits. A first fluid conduit terminates in a first quick connect connector and a second fluid conduit terminates in a second quick connect connector that mates with first quick connect connector in order to provide fluid communication between the first and second fluid conduits. In one example, a compute node includes a cooling circuit coupled between two quick connect connectors that may blind mate with two mating quick connect connectors secured to a fluid supply manifold and a fluid return manifold, respectively. A typically cooling circuit may include a fluid cooled heat exchanger in thermal contact with a heat-generating device, such as a microprocessor.

The two quick connect connectors of a quick connect coupling are typically dissimilar but complimentary, such as one male connector and one female connector. Typically, male and female quick connect connectors may be coupled together regardless of the direction of fluid flow or the direction of movement of one connector to the other connector. Accordingly, in the present examples, the male and female quick connect connectors will be equally operable if their positions are reversed. Most preferably, each of the quick connect connectors will include an automatic shut off valve that prevents fluid flow when disconnected.

The rigid structure of the first and second quick compliant connector assemblies may take various forms so long as the rigid structure may be secured to the compute node and form the first and second collars. For example, the rigid structure may form a housing or casing around a quick connect connector. Optionally, each of the first and second collars may form an inwardly and rearwardly angled surface, such as a frustoconical surface.

In one preferred configuration, the quick connect connector is centered in the first and second collars of the compliant connector assembly unless acted upon by a force overcoming the spring and pushing the first and second shoulders of the quick connect connector out of contact with the first and second collars of the compliant connector assembly.

In another preferred configuration, the quick connect connector is allowed to tilt to various angles in order to align with a mating quick connect connector despite any initial misalignment between the two mating quick connect connectors. The range of angles is determined by the spacing between the collars/shoulders, as well as the relative dimensions of the quick connect connector and the collars. For example, when the quick connect connector is in a retracted position, the compliant connector assembly may allow the quick connect connector to move in a lateral direction, vertical direction, longitudinal direction and at an angle relative to a longitudinal axis defined by an extended position of the quick connect connector.

Optionally, the compute nodes may share common chassis power supplies, fans, and midplane, and have a known "blade" style of system architecture. Many of these shared features may be provided from the rear of the chassis along with the fluid supply and return conduits. As multiple compute nodes are packaged into a chassis or rack the main vertical "trunk" cooling lines may be routed vertically from bottom to the top of the rack. These lines are large and heavy and are best placed at the rear of the rack. This location allows them to remain stationary and affords the ability to assemble, remove, or service each compute node from the customary front location of the rack. Since the compliant connector

assembly is affixed to the compute node itself, the compliant connector assembly can be quickly and easily serviced by removing the compute node from the chassis.

Another embodiment of the present invention provides an apparatus comprising a compute node configured to be received within a chassis bay, and a first compliant connector assembly secured to a rearward end of the compute node. The first compliant connector assembly includes a rigid structure having first and second collars, a first quick connect connector having first and second shoulders, and a first spring biasing the first quick connect connector in the rearward direction. The first collar and the first shoulder of the first compliant connector assembly form an inwardly and rearwardly angled contact surface there between, wherein the second collar and the second shoulder of the first compliant connector assembly form an inwardly and rearwardly angled contact surface there between, and wherein the first quick connect connector is oriented in a rearward direction for blind mating with a second quick connect connector within the chassis bay. Optionally, the apparatus may further comprise a second compliant connector assembly secured to the rearward end of the compute node, wherein the second compliant connector assembly includes a rigid structure having first and second collars, a third quick connect connector having first and second shoulders, and a second spring biasing the third quick connect connector in the rearward direction. The first collar and the first shoulder of the second compliant connector assembly may form an inwardly and rearwardly angled contact surface there between, and the second collar and the second shoulder of the second compliant connector assembly may form an inwardly and rearwardly angled contact surface there between, wherein the third quick connect connector is oriented in a rearward direction for blind mating with a fourth quick connect connector within the chassis bay. Still further, the apparatus may include or implement any one or more additional feature described in regard to other embodiments disclosed herein.

Yet another embodiment of the present invention provides an apparatus comprising a rigid structure having first and second collars, a quick connect connector having first and second shoulders, and a spring biasing the quick connect connector toward an extended position with the first shoulder against the first collar and the second shoulder against the second collar. The first collar and the first shoulder form an inwardly and rearwardly angled contact surface there between, and the second collar and the second shoulder form an inwardly and rearwardly angled contact surface there between. The quick connect connector is centered in the first and second collars unless acted upon by a force overcoming the spring and pushing the quick connect connector to a retracted position with the first and second shoulders out of contact with the first and second collars. Optionally, each of the first and second collars may form an inwardly and rearwardly angled surface, such as a frustoconical surface.

Embodiments of the present invention provide a compliant connector assembly that includes a quick connect connector that is in an initially fixed position to facilitate initiate engagement with a mating connector (without binding) and then is released to float or move upon initial force from the mating connector. The compliant connector facilitates a blind docking or blind mating fluid coupling that allows for angular and linear misalignment between mating quick connect connectors. In other words, the compliant connector assembly provides initial nominal axial alignment between mating quick connect connectors, but allows for some initial misalignment by allowing the quick connect connector to move in response to forces applied as the two connectors are pushed together.

FIG. **1** is a perspective view of a compute node **10** being installed into a bay **22** of a chassis **20** or rack in order to blind mate a pair of fluid couplings. The bay **22** is configured to receive the compute node **10**, such as using side rails **21**, **23** that constrain the compute node **10** to slide in a rearward direction (see arrow **25**) and provide nominal alignment of certain quick connect connectors.

The chassis **20** includes a fluid supply conduit **24**, a fluid return conduit **26**, a first quick connect connector **28** that is fluidically coupled to the fluid supply conduit **24**, a second quick connect connector **30** that is fluidically coupled to the fluid return conduit **26**. The first and second quick connect connectors **28**, **30** are secured in a fixed position at the back of the bay **22** and are oriented in a forward direction into the bay **22**. The compute node **10** has a rearward end **12** securing a first and second compliant connector assemblies **40**. Each compliant connector assembly **40** includes a quick connect connector **42** oriented in a rearward direction so that installing the compute node **10** within the bay **22** provides nominal alignment of the quick connect connectors **42** on the compute node **10** with the quick connect connectors **28**, **30** on the fluid supply and return conduits **24**, **26**.

The compute node **10** also includes a cooling fluid circuit **14** that includes a fluid supply tube **15**, a fluid return tube **17**, and a fluid-cooled heat exchanger **16** fluidically coupled between the fluid supply tube **15** and the fluid return tube **17**. A cooling fluid, such as chilled water, may pass through the heat exchanger **16** to cool a heat-generating component, such as a microprocessor (not shown), in thermal contact communication with the heat exchanger **16**. Typically, the heat-generating component will be in direct contact with the heat exchanger. Once the mating quick connect connectors **28**, **42** are coupled to supply the cooling fluid and the mating quick connector connectors **30**, **42** are coupled to return the warmed fluid, then the cooling fluid circuit is operational. For example, a cooling fluid from a chilled fluid source (not shown) is supplied to the fluid supply conduit or manifold **24**. The cooling fluid may then flow through the mated connectors **28**, **42**, through the fluid supply tube **15** to the heat exchanger **16** where heat from the heat-generating component is transferred into the cooling fluid, which becomes warm. The warmed fluid passes out of the heat exchanger **16**, through the fluid return tube **17**, and through the mated connectors **30**, **42** to the fluid return conduit **26** before being discarded or returned to the chilled fluid source.

It should be noted that other components and features of a compute node **10** and a chassis **20** are not shown, but may still be included. For example, the rear end **12** of the compute node **10** may include one or more electronic connectors for blind mating with one or more mating electronic connectors of the chassis **20**. Optionally, the chassis **20** may include a midplane including connectors for blind mating with a plurality of compute nodes across a plurality of bays formed in the chassis **20**, where each bay preferably includes quick connect connectors **28**, **30**.

FIG. **2**A is a cross-sectional diagram of a compliant connector assembly **40** including a quick connect connector **42** that is axially aligned for coupling to a mating fixed quick connect connector **28**. The quick connect connector **42** has a first shoulder **44** and a second shoulder **46**, and the compliant connector assembly **40** includes a rigid structure **50** having a first collar **52** and a second collar **54**. The distance between the first and second shoulders **44**, **46** is the same as the distance between the first and second collars **52**, **54**, such that the first shoulder **44** can contact the first collar **52** at the same time that the second shoulder **46** contacts the second collar **54**.

The first collar **52** and the first shoulder **44** form an inwardly and rearwardly angled contact surface there between, and the second collar **54** and the second shoulder **46** form an inwardly and rearwardly angled contact surface there between. As shown, it is not necessary for both the collar and the shoulder that contacts the collar to be angled inwardly and rearwardly, although this is shown between the second collar **54** and the second shoulder **46**. Alternatively, an inwardly and rearwardly angled contact surface may be formed between a collar is angled and a shoulder that is squared off (or some other shape), as shown by the second collar **52** and the second shoulder **44**, or between a collar that is squared off (or some other shape) and a shoulder that is angled. The important feature is that the collar and shoulder form an inwardly and rearwardly angled contact surface there between, such that the quick connect connector **42** is secured when in an extended position as shown in FIG. **2**A. Optionally, the quick connect connector **42** may be positioned in a manner that the connector may be described as being "centered" within the collars **52**, **54**.

The compliant connector assembly **40** further includes a spring **60** biasing the quick connect connector **42** in the rearward direction (see arrow **25**). The spring **60** is shown in the form of a compression spring disposed between a spring shoulder **56** on the quick connect connector **42** and a spring seat **62** that slidably contacts the rigid structure **50** around the second collar **54**. Accordingly, the spring **60** biases the quick connect connector **42** in a rearward direction (see arrow **25**), such that the first shoulder **44** is pushed against the first collar **52**, and the second shoulder **46** is pushed against the second collar **54**. Due to the inwardly and rearwardly angled contact surfaces formed between the shoulders and collars, the shoulders move to an extended position. As shown, in FIG. **2**A, the extended position moves the quick connect connector **42** to a "centered" position.

The quick connect connector **42** in the compliant connector assembly **40** is shown as a female connector and the quick connect connector **28** secured to the fluid supply conduit **24** is shown as a male connector. It should be recognized that the male and female connectors may be reversed, such that the male connector is on the compliant connector assembly and the female connector is on the fluid supply conduit. Furthermore, both of the quick connect connectors **28**, **42** are shown having automatic shut off valves **29**, **59**, but the details of quick connect connectors with automatic shut off valves is known to those having ordinary skill in the art and is not repeated here.

The compliant connector assembly **40** is secured to the compute node **10** via a bracket **57** that is attached to, or forms part of, the rigid structure **50**. As shown, the compliant connector assembly **40** is positioned so that the quick connect connector **42** extends from the back end **12** of the compute node **10**. Still further, the quick connect connector **42** is shown including a fitting **58** for securing a fluid tubing, such as the fluid supply tube **15**. Although the two quick connect connectors **28**, **42** are not coupled together, an axial center line **48** of the quick connect connector **42** is aligned with the axial center line **27** of the quick connect connector **28**.

FIG. **2**B is a cross-sectional diagram of the quick connect connector **42** coupled to the fixed quick connect connector **28** of FIG. **2**A to provide fluid communication there between. As a result of the compute node **10** being moved in the rearward direction in the chassis bay, the connectors **28**, **42** engage to form a fluid seal between the connectors and cause the automatic shut off valves **29**, **59** to open.

Since the two quick connect connectors **28**, **42** were precisely axially aligned and precisely spaced apart prior to connection, the connectors **28**, **42** were able to be coupled without the shoulders **44**, **46** necessarily disengaging from the collars **52**, **54**. The figures below detail situations where the connectors are not precisely axially aligned or spaced apart.

FIG. **3**A is a cross-sectional diagram of the compliant connector assembly **40** having a quick connect connector **42** that is angularly misaligned with a mating fixed quick connect connector **28**. Within a range of dimensional tolerance, the connectors **28**, **42** make initial contact and the leading end of the male connector enters a portion of the opening in the female connector. However, due to the axial misalignment, the connectors **28**, **42** are unable to couple in this position. Under additional force applied on the compute node **10** to push the node into the bay, the "fixed" connector **28** pushes back on the "floating" connector **42** with sufficient force to overcome the biasing force in the spring **60** (compress the spring) and retract the floating connector **42** in a longitudinal direction (toward the left as shown in FIG. **3**A). In the retracted position, the first shoulder **44** has disengaged the first collar **52**, and the second shoulder **46** has disengaged the second collar **54**, such that the connector **42** may be said to "float". Accordingly, since the portions of the quick connect connector **42** that now extend through the collars **52**, **54** have dimensions that are smaller than the shoulders **44**, **46**, there is freedom for the quick connect connector **42** to move in two dimensions (vertically and laterally). Furthermore, since the two (proximal and distal) portions of the connector **42** are not constrained to move in the same direction, the floating connector **42** may move to adjust the angle of its axial centerline **48**, within physical limits established by the collars, to match the angle of the axial centerline **27** of the fixed connector **28**.

FIG. **3**B is a cross-sectional diagram of the compliant connector assembly **40** with the floating quick connect connector **42** coupled to the fixed quick connect connector **28** of FIG. **3**A to provide fluid communication there between. While the fixed connector **28** has stayed in the same position and angle, the rearward end of the floating connector **42** has moved vertically lower, the proximal end of the floating connector **42** has moved vertically upward, and the entire floating connector **42** has moved longitudinally further in a retraction direction (leftward in FIG. **3**B). The spring **60** is highly compressed and the spring seat **62** has moved upward along with the proximal end of the floating connector **42**. In other details, the connectors **28**, **42** operate in the same manner as in FIG. **2**A and FIG. **2**B. Furthermore, when the connectors **28**, **42** are decoupled, the spring **60** will cause the floating connector **42** to return to the position shown in FIG. **2**A.

FIG. **4**A is a cross-sectional diagram of the compliant connector assembly **40** having a floating quick connect connector **42** that is vertically misaligned (offset) with a mating fixed quick connect connector **28**. While the axial centerlines **48**, **27** are parallel, they are offset by a distance, such that the fixed connector **28** is vertically elevated relative to the floating connector **42**. At the point of initial contact as shown, the connectors **28**, **42** make contact and engage such that the leading end of the fixed male connector **28** enters the opening in the floating female connector **42**. However, without an adjustment in the alignment of the connectors **28**, **42**, the coupling cannot be completed.

FIG. **4**B is a cross-sectional diagram of the compliant connector assembly **40** with the floating quick connect connector **42** coupled to the fixed quick connect connector **28** of FIG. **4**A to provide fluid communication there between. As shown, the first shoulder **44** has disengaged the first collar **52**, and the second shoulder **46** has disengaged the second collar **54**. However, the insertion forces on the compute node **10** cause the both the proximal and distal portions of the floating

connector **42** to move vertically upward to account for the initial offset between the connectors **28**, **42**. This and other misalignments may be tolerated in accordance with one or more embodiment of the present invention.

The terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting of the invention. As used herein, the singular forms "a", "an" and "the" are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will be further understood that the terms "comprises" and/or "comprising," when used in this specification, specify the presence of stated features, integers, steps, operations, elements, components and/or groups, but do not preclude the presence or addition of one or more other features, integers, steps, operations, elements, components, and/or groups thereof. The terms "preferably," "preferred," "prefer," "optionally," "may," and similar terms are used to indicate that an item, condition or step being referred to is an optional (not required) feature of the invention.

The corresponding structures, materials, acts, and equivalents of all means or steps plus function elements in the claims below are intended to include any structure, material, or act for performing the function in combination with other claimed elements as specifically claimed. The description of the present invention has been presented for purposes of illustration and description, but it is not intended to be exhaustive or limited to the invention in the form disclosed. Many modifications and variations will be apparent to those of ordinary skill in the art without departing from the scope and spirit of the invention. The embodiment was chosen and described in order to best explain the principles of the invention and the practical application, and to enable others of ordinary skill in the art to understand the invention for various embodiments with various modifications as are suited to the particular use contemplated.

What is claimed is:

1. An apparatus comprising:

a chassis including a fluid supply conduit, a fluid return conduit, a first quick connect connector that is fluidically coupled to the fluid supply conduit, a second quick connect connector that is fluidically coupled to the fluid return conduit, and a bay configured to receive a compute node, wherein the first and second quick connect connectors are secured in a fixed position at a back of the bay and oriented in a forward direction into the bay;

a compute node having a rearward end securing a first compliant connector assembly and a second compliant connector assembly, wherein the first compliant connector assembly includes a third quick connect connector oriented in a rearward direction so that installing the compute node within the bay provides nominal alignment of the third quick connect connector with the first quick connect connector, and wherein the second compliant connector assembly includes a fourth quick connect connector oriented in a rearward direction so that installing the compute node within the bay provides nominal alignment of the fourth quick connect connector with the second quick connect connector;

wherein the first compliant connector assembly includes a rigid structure having first and second collars, wherein the third quick connect connector has first and second shoulders, wherein the first collar and the first shoulder form an inwardly and rearwardly angled contact surface there between, wherein the second collar and the second shoulder form an inwardly and rearwardly angled contact surface there between, and wherein the first compliant connector assembly further includes a first spring biasing the third quick connect connector in the rearward direction; and

wherein the second compliant connector assembly includes a rigid structure having first and second collars, wherein the fourth quick connect connector has first and second shoulders, wherein the first collar and the first shoulder form an inwardly and rearwardly angled contact surface there between, wherein the second collar and the second shoulder form an inwardly and rearwardly angled contact surface there between, and wherein the second compliant connector assembly further includes a second spring biasing the fourth quick connect connector in the rearward direction.

2. The apparatus of claim **1**, wherein the first and second collars each form an inwardly and rearwardly angled surface.

3. The apparatus of claim **2**, wherein the first and second collars each form a frustoconical surface.

4. The apparatus of claim **1**, wherein the third quick connect connector is centered in the first and second collars of the first compliant connector assembly unless acted upon by a force overcoming the first spring and pushing the first and second shoulders of the third quick connect connector out of contact with the first and second collars of the first compliant connector assembly; and

wherein the fourth quick connect connector is centered in the first and second collars of the second compliant connector assembly unless acted upon by a force overcoming the first spring and pushing the first and second shoulders of the fourth quick connect connector out of contact with the first and second collars of the second compliant connector assembly.

5. The apparatus of claim **1**, wherein the third quick connect connector is allowed to tilt to various angles in order to align with the first quick connect connector despite any initial misalignment between the first and third quick connect connectors; and

wherein the fourth quick connect connector is allowed to tilt to various angles in order to align with the second quick connect connector despite any initial misalignment between the second and fourth quick connect connectors.

6. The apparatus of claim **1**, wherein, when the third quick connect connector is in a retracted position, the first compliant connector assembly allows the third quick connect connector to move in a lateral direction, vertical direction, longitudinal direction and at an angle relative to a longitudinal axis defined by an extended position of the third quick connect connector; and

wherein, when the fourth quick connect connector is in a retracted position, the first compliant connector assembly allows the fourth quick connect connector to move in a lateral direction, vertical direction, longitudinal direction and at an angle relative to a longitudinal axis defined by an extended position of the fourth quick connect connector.

7. The apparatus of claim **1**, wherein the compute node includes a cooling circuit coupled between the third and fourth quick connect connectors.

8. The apparatus of claim **1**, wherein each of the quick connect connectors include an automatic shut off valve that prevent fluid flow when disconnected.

9. An apparatus comprising:

a compute node configured to be received within a chassis bay; and

a first compliant connector assembly secured to a rearward end of the compute node, wherein the first compliant

connector assembly includes a rigid structure having first and second collars, a first quick connect connector having first and second shoulders, and a first spring biasing the first quick connect connector in the rearward direction, wherein the first collar and the first shoulder of the first compliant connector assembly form an inwardly and rearwardly angled contact surface there between, wherein the second collar and the second shoulder of the first compliant connector assembly form an inwardly and rearwardly angled contact surface there between, and wherein the first quick connect connector is oriented in a rearward direction for blind mating with a second quick connect connector within the chassis bay.

10. The apparatus of claim **9**, further comprising:

a second compliant connector assembly secured to the rearward end of the compute node, wherein the second compliant connector assembly includes a rigid structure having first and second collars, a third quick connect connector having first and second shoulders, and a second spring biasing the third quick connect connector in the rearward direction, wherein the first collar and the first shoulder of the second compliant connector assembly form an inwardly and rearwardly angled contact surface there between, wherein the second collar and the second shoulder of the second compliant connector assembly form an inwardly and rearwardly angled contact surface there between, and wherein the third quick connect connector is oriented in a rearward direction for blind mating with a fourth quick connect connector within the chassis bay.

11. The apparatus of claim **9**, wherein the compute node includes a cooling circuit coupled between the first and second quick connect connectors.

12. The apparatus of claim **9**, wherein the first and second collars each form an inwardly and rearwardly angled surface.

13. The apparatus of claim **12**, wherein the first and second collars each form a frustoconical surface.

14. The apparatus of claim **9**, wherein the first quick connect connector is centered in the first and second collars of the first compliant connector assembly unless acted upon by a force overcoming the first spring and pushing the first and second shoulders of the first quick connect connector out of contact with the first and second collars of the first compliant connector assembly.

15. The apparatus of claim **9**, wherein the first quick connect connector is allowed to tilt to various angles in order to align with the second quick connect connector despite any initial misalignment between the first and second quick connect connectors.

16. The apparatus of claim **9**, wherein, when the first quick connect connector is in a retracted position, the first compliant connector assembly allows the first quick connect connector to move in a lateral direction, vertical direction, longitudinal direction and at an angle relative to a longitudinal axis defined by an extended position of the first quick connect connector.

17. The apparatus of claim **9**, wherein the first and second quick connect connectors each include an automatic shut off valve that prevents fluid flow when disconnected.

18. An apparatus comprising:

a rigid structure having first and second collars;

a quick connect connector having first and second shoulders; and

a spring biasing the quick connect connector toward an extended position with the first shoulder against the first collar and the second shoulder against the second collar, wherein the first collar and the first shoulder form an inwardly and rearwardly angled contact surface there between, wherein the second collar and the second shoulder form an inwardly and rearwardly angled contact surface there between, wherein the quick connect connector is centered in the first and second collars unless acted upon by a force overcoming the spring and pushing the quick connect connector to a retracted position with the first and second shoulders out of contact with the first and second collars.

19. The apparatus of claim **18**, wherein the first and second collars each form an inwardly and rearwardly angled surface.

20. The apparatus of claim **19**, wherein the first and second collars each form a frustoconical surface.

* * * * *